

BLACK & VEATCH

South Florida Water Management District
EAA Reservoir A-1 Basis of Design Report

January 2006

APPENDIX 6-5A

**REVISED PUMPING AND DISCHARGE FACILITIES
TECHNICAL MEMORANDUM SUBMITTED OCTOBER 13, 2005**

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The following technical memorandum has been updated since its original submission to include the water balance models (WBM) used in determining the pump station size.

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TECHNICAL MEMORANDUM SUBMITTED JULY 29, 2005**

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TECHNICAL MEMORANDUM

South Florida Water Management District
EAA Reservoir A-1
Work Order No. 7

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Task 7.1.3.1.2 Pumping and Discharge Facilities Technical Memorandum

To: Distribution

From: Ted Stolinski, Jim Grassi and Norm Jagels

1. INTRODUCTION

In October 2003, South Florida Water Management District (District) decided to pursue a “Dual Track” for the Everglades Agricultural Area (EAA) Reservoir project. While the multi-agency Project Delivery Team, lead by the Corps of Engineers, continues to develop the Project Implementation Report, the District is proceeding with the design of a reservoir (designated EAA Reservoir A-1 Project) located on land acquired through the Talisman exchange in the Everglades Agricultural Area.

The purpose of the Project as defined in the CERP is to capture EAA Basin runoff and releases from Lake Okeechobee. The facilities will be designed to improve the timing of environmental water supply deliveries to STA 3/4 (Storm Water Treatment Area 3/4) and the WCA’s (Wetland Conservation Areas), reduce Lake Okeechobee regulatory releases to the estuaries, meet supplemental agricultural irrigation demands, and increase flood protection within the EAA.

The focus of this Pumping and Discharge Facilities Technical Memorandum is primarily the pumping facilities. Discharge facilities are identified to the extent necessary to define the operation of each alternative, but the sizing of discharge facilities is covered in the Gates Technical Memorandum prepared under Work Order 10.

2. OBJECTIVES

The objectives of this Technical Memorandum are to:

- Summarize the various pumping and discharge alternatives for which costs were developed
- Discuss cost implications of various construction methods for construction of the five originally selected pumping and discharge alternatives and additional alternative developed later.
- Summarize the cost of each alternative.

This memorandum describes the cost impacts of each alternative. These cost impacts are to be used in conjunction with other considerations identified in WO7 to develop a final recommendation.

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3. PUMPING AND DISCHARGE

3.1 General

As discussed at the Workshop on May 24, 2005, five pumping and discharge alternatives were selected for consideration. Later two additional alternatives were added and variations of Alternatives 2 through 5 were added where provisions were made to pump all flows into the A1 Reservoir before passing to the STA 3/4 Treatment Area. The original alternatives are designated as 1, 2, 3, 4 and 5. Alternatives 6 and 7 were added later and the alternatives where all flows are pumped to the A1 Reservoir before passing to STA 3/4 are designated Alternatives 2A, 3A, 4A, and 5A. In general, all alternatives are based on the addition of a new Northeast Pump Station to be located adjacent to the North New River Canal in the northeast corner of the A1 Reservoir site combined with different levels of optimization of the existing pumping stations G-370 and G-372. Figures 8 to 18 illustrate the pumping and discharge alternatives and are discussed in the following paragraphs. Pumping Station G-372 modification options for each alternative are shown on Figure 1.

The capacity of the Northeast Pump Station is based on the capacity of the North New River Canal and the amount of water available during wet or dry periods. Because of the irregular physical characteristics of the canal, its capacity varies depending on the location of the pumping facilities located along its length. Because of the additional travel distance required, the capacity available for flows pumped from the existing G-370 site tends to be lower than that for the anticipated location of the new Northeast Pump Station. In addition, the available capacity is less for dry weather scenarios in which flow enters the canal from either Lake Okeechobee or from the intersection with the Bowles and Cross canals, than for wet weather scenarios which include local drainage.

The operating level of the A1 reservoir will fluctuate between Elev. 8.6 and 20.6 NGVD. The normal operating level of the STA 3/4 supply canal is about 13.6 with a maximum operating level of 16.6. Both G-370 and G-372 are designed to pump to a water elevation of 13.6 NAVD in the STA 3/4 supply canal. Pumping to higher water elevations will rapidly diminish their respective capacities. The difference in operating levels offers opportunities for gravity flow between the reservoir and supply canal under certain conditions, but will require pumped flow for other conditions. This is reflected in each alternative.

3.2 Pumping and Discharge, Alternatives 1 through 7 and 2A through 5A

3.2.1 Alternative 1

This alternative includes the installation of a new Northeast Pump Station to pump into the A1 reservoir with no modifications to pumping stations G-370 or G-372. G-370 will continue to pump up to 2775 cfs from the North New River Canal to the STA 3/4 supply canal and G-372 will continue to pump up to 3700 cfs from the Miami Canal to the STA 3/4 supply canal. From the supply canal, flow from both stations is discharged directly into STA 3/4. Pumping capacity into the A1 Reservoir from the North New River Canal is provided by construction of the new Northeast Pumping Station. The structure of the pumping station will be constructed to provide for a capacity of 4,900 cfs, but pumps installed with a capacity of 3,200 cfs. This would allow installing additional pumps in the future for increased capacity. The static pumping head of the Northeast pumping station is from Elevation 8.6 to 20.6 feet.

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A gate structure will be located adjacent to the new pumping station to allow discharge of flow to the North New River Canal to meet agricultural needs. This gate structure will allow gravity discharge to water surface elevation 8.6. Gate structures will also be located between the reservoir and the STA 3/4 supply canal to allow gravity discharge when water surface levels in the reservoir are between 20.6 and 13.6.

3.2.2 Alternatives 2 and 2A

This alternative is similar to Alternative 1 with the exception that G-370 and G-372 will be used to pump into the A1 reservoir under certain conditions. The alternative includes the installation of a new Northeast Pump Station to pump into the A1 reservoir and no further modifications will be made to pumping stations G-370 or G-372. G-370 will continue to pump up to 2775 cfs from the North New River Canal to the STA 3/4 supply canal and G-372 will continue to pump up to 3700 cfs from the Miami Canal to the STA 3/4 supply canal. Gate structures will be located between the STA 3/4 supply canal and the reservoir to allow gravity discharge from the canal to the reservoir when the reservoir water level is less than elev. 16.6. Water can also be discharged from the supply canal to the STA. Once the water level in the reservoir exceeds elevation 16.6, all flow into the reservoir will be from the Northeast Pump Station. The pumping station will have an initial capacity of 3,200 cfs with the structural designed for adding pumps to increase capacity to 4,900 cfs. The static pumping head of the Northeast pumping station will be from Elevation 8.6 to 20.6 feet.

Similar to Alternative 1, a gate structure will be located adjacent to the new pumping station to allow discharge of flow to the North New River Canal to meet agricultural needs. This gate structure will allow gravity discharge to water surface elevation 8.6. The gate structures located between the reservoir and the STA 3/4 supply canal can also be used to allow gravity discharge from the reservoir to the supply canal when water surface levels in the reservoir are between 20.6 and 13.6.

Alternative 2A involves adding 4 gate structures to allow discharging water from the A1 Reservoir when its water level exceeds elevation 13.6, to the STA 3/4 supply canal while water continues to be pumped into the reservoir by Pumping Stations G-370 and G-372. The two gate structures shown under Alternative 2 used for filling the reservoir and for discharging from the reservoir to the supply canal will normally only be used for filling the reservoir. Additional gate structures will be added to block the pump stations discharge from flowing to the supply canals and direct it to the reservoir. Two gate structures would be added, dedicated to releasing water from the reservoir to the supply canal when reservoir levels are between 13.6 and 20.6. One gate structure would be located west of Control Structure G-383 and one east of G-383.

3.2.3 Alternatives 3 and 3A

This alternative includes the installation of a new Northeast Pump Station combined with modifications to the G-370 pump station sufficient to allow pumping from this station to a water surface elevation of 20.6, that of a full reservoir. There are a number of modification options available, each modification is progressively more complex resulting in greater capacity, and each is discussed in greater detail in section 4.3. The resulting capacities for each modification alternative range from 1020 cfs to 2775 cfs and are summarized in Figure 1. Each of the modification alternatives would also require canal modifications to allow diversion of the G-370 flow into the reservoir, because the reservoir and the supply canal will not operate on the same water elevation. These modifications are discussed in detail in section 4.3.1. The required

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capacity of the Northeast Pump Station decreases as the capacity of G-370 increases. The wet condition and dry condition capacity of the new Northeast pumping station will depend on the capacity of the modified G-370, and is shown on Figure 2. The pumping rate for these conditions is shown on Figures 3 and 4.

This alternative includes no modifications to pumping station G-372. A gate structure near the A1 Reservoir on the STA 3/4 supply canal allows up to 3700 cfs to be pumped by G-372 from the Miami Canal, through the supply canal to the reservoir up to water surface elevation 16.6. When reservoir water surface elevations exceed elev. 16.6, G-372 flow is pumped directly to STA3/4 through the supply canal.

Gate discharge structures for this alternative are similar to the preceding alternatives. A gate structure will be located adjacent to the new pumping station to allow discharge of flow to the North New River Canal to meet agricultural needs. This gate structure will allow gravity discharge to water surface elevation 8.6. The gate structures located between the reservoir and the STA 3/4 supply canal can allow gravity discharge from the reservoir to the supply canal when water surface levels in the reservoir are between 20.6 and 13.6.

Alternative 3A involves adding the same 4 gate structures described for Alternative 2A to allow pumping all water from pumping Stations G-370 and G-372 into the A1 Reservoir while at the same time withdrawing water from the reservoir and discharging it into the supply canal.

3.2.4 Alternatives 4 and 4A

This alternative builds upon Alternative 3 in that it expands those alternatives by including a modification to pumping station G-372 and the supply canal from G-372 to A1 Reservoir to allow flows from that pump station to be pumped to a water surface elevation of 20.6. Modifications to G-372 under this alternative would be progressively

more complex, essentially in alignment with those identified for G-370 under Alternative 3. The modifications to G-370 would be identical to those described in Alternative 3.

Because the existing supply canal embankment would not be able to accommodate water surface elevation of 20.6, this alternative includes building up the embankments to an elevation of 24.6 from G-372 to the A1 reservoir. A gate structure would be constructed in the supply canal at this location to allow segregation between the segment of the supply canal and that portion of the supply canal adjacent to the STA to allow these segments to operate at different water surface elevations, one to match the water surface elevation in the reservoir, the other to operate as required to feed the STA.

Under this option, all flow would be pumped through the A1 Reservoir and then discharged to the STA 3/4 supply canal. As with the other alternatives, a gate structure will be located between the reservoir and the STA 3/4 supply canal to allow gravity discharge from the reservoir to the supply canal when water surface levels in the reservoir are between 20.6 and 13.6. A gate structure will be located adjacent to the new pumping station to allow discharge of flow to the North New River Canal to meet agricultural needs. This gate structure will allow gravity discharge to water surface elevation 8.6.

Alternative 4A involves adding 2 gate structures dedicated to withdrawing water from the A1 Reservoir.

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3.2.5 *Alternatives 5 and 5A*

This alternative would be the same as Alternative 4 in all aspects except that rather than modify the G-372 pump station and the supply canal between the pump station and the reservoir, a new booster pumping station would be located in the southeast corner of the reservoir to boost the 3700 cfs flow from pumping station G-372 to the A1 Reservoir water surface elevation 20.6. All other features of Alternative 4 would be included in this alternative.

Alternative 5A involves adding a gate structure near Pumping Station G-370 to release water from the A1 Reservoir to the STA 3/4 supply canal and a gate, structure on the supply canal downstream of the new booster pumping station.

3.2.6 *Alternative 6*

Alternative 6 includes a new booster pumping station to pump water from the supply canal into the A1 Reservoir up to a full reservoir at a water surface elevation of 20.6. The Northeast Pump Station would not be provided and Pumping Stations G-370 and G-372 would not be modified. Gate structures would be provided to discharge water from the A1 Reservoir to the supply canal when the reservoir water surface elevation was above elevation 13.6. A second gate structure would be provided to allow discharge of flow from the reservoir to the North New River Canal to an elevation of 8.6.

3.2.7 *Alternative 7*

Alternative 7 is similar to Alternative 6, except that a 1,000 cfs Northeast Pump Station is included.

4. PUMPING STATION AND DISCHARGE MODIFICATIONS

Pumping Station G-370 contains 3 vertical pumps and Pumping Station G-372 contains 4 vertical pumps, all rated at 925 cfs. Each pump has a formed intake and siphon discharge tunnel. All pumps are driven by internal combustion engines. Each engine is connected to its associated pump through a right-angle gear reducer.

The Existing Pumping Station G-370 was originally designed to pump 2175 cfs to a STA 3/4 Feeder Canal Design Elevation of 13.6 feet. However in the procurement of the original pumping equipment, Flow serve proposed providing basically identical pumps at G-370 and G-372. This resulted in providing 3 pumps rated 925 cfs increasing pumping capacity at G-370 to 2775 cfs at STA 3/4 Feeder Canal Design Elevation of 13.6 feet. However while the pumping station can pump 2775 cfs, it is reported that hydraulic problems in the supply canals do not currently permit continuous operation at this flow rate. At maximum STA 3/4 Feeder Canal Elevation of 16.6 feet, the larger pumps at G-370 can pump approximately 2340 cfs. Slightly higher pumping heads are possible with the existing propellers, but the pumping station is limited by the engine output capacity from pumping at discharge heads above Elevation 16.6. For pump discharge elevations greater than 16.6, all pumping will come from sources other than an un-modified G-370.

The existing 3700 cfs capacity Pumping Station G-372 contains 4 pumps, each rated at 925 cfs at a discharge elevation of 15.6. This is 2 feet higher than the design discharge elevation of Pumping Station G-370 to account for the head losses in the canal transporting the water to the STA 3/4 supply canal. Pumping Station G-372 was designed to also operate at a discharge

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elevation of 17.6 but at a reduced flow. As with Station G-370, engine output capacity limits pumping at discharge heads about Elevation 17.6.

Each station is also provided with seepage pumps to collect seepage from the discharge canals and pump it back into the discharge canals. At Pumping Station G-372 the option exists to discharge seepage into the Holey Land Inflow Canal. Each station has 3 seepage pumps rated at 75 cfs. The capacity is based on 2 pumps operating with a third acting as standby. The pumps are driven by electric motors and are equipped with adjustable frequency drives to permit matching pumping rate with inflow rate. Power for the pump motors are normally provided by a commercial power supply, but can also be provided by on-site engine-generators.

The suction to the main pumps and seepage pumps is protected by trash screens that are automatically cleaned by a picker rake mechanism.

The engine-generators are located inside the station, sized to allow operation of the station during loss of commercial power.

Support systems provided for the engines driving the main pumps include:

- Fuel oil supply system consisting of a fuel oil receiving pump, storage tanks, and transfer pumps for transferring fuel oil to day tanks at the engines
- Lube oil supply system including a storage tank and transfer pumps provided to automatically make-up oil lost from the engine crankcase
- Waste lube oil collection system provided to collect oil from the engines and engine-generators
- Cooling water supply system for the engines and the gear reducers
- Compressed air system provided for starting the engines

A fresh water supply system provides water for a lubricating water supply system for water lubricated pump bearings and for a potable water supply system

4.1 *Modifications to Pumping Stations G-370 and G-372 in Alternatives 3, 3A, 4, 4A, 5, and 5A*

The pumping station modification Options A thru F are shown on Figure 1.

The existing engines at both pumping stations operate at 720 rpm and are naturally aspirated. The engines can be modified to provide additional power by increasing the engine speed and with the addition of a turbocharger on the engine. These two modifications together can potentially increase the output capacity by approximately 65 percent at G-370 and by approximately 100 percent at G-372. This additional power can be used to increase the pumping head available, permitting the pumping units to pump to a reservoir elevation of 20.6 feet.

However in order to take advantage of the available additional horsepower, a number of modifications to the engine auxiliary systems and the pumping station must be made. These include just about every mechanical system within the pumping station related to the operation of the engine. Many of these systems may have to be upgraded or replaced. Equipment and

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systems potentially affected by the increasing the engine horsepower rating and pump head include the following.

- Engine Exhaust System – Increased output capacity of the engine will increase the volume of exhaust gas. The increased flow through the existing silencers and piping will impose additional backpressure on the engine, which is not acceptable for proper operation of the engine. This will require replacing the existing exhaust system with a larger exhaust silencers and larger diameter exhaust pipe. The existing exhaust pipe penetrations in the building wall will have to be modified to accommodate the increased size of exhaust pipe. Additionally, if the engines are turbocharged, this significantly changes the support of the exhaust system. Typically it is not permitted to transmit any forces to the turbochargers, so the weight of the piping system and any forces due to thermal expansion must be supported independently of the engine.
- Fuel System – Increasing the output capacity of the engines will increase the fuel consumption, however it is anticipated that the existing capacity of the main fuel storage tanks are still suitable to provide the desired five days of fuel storage. It is also anticipated that the current fuel pumps are suitable for the increased flow requirements. A new day tank will be required to provide additional capacity to prevent the fuel oil pumps from cycling excessively.
- Engine Jacket Water, Engine Oil, and Gear Reducer Cooling System – Cooling is critical for proper operation of the engine. Increasing the output capacity up to 65 percent will result in about the same increase in cooling requirements. Approximately one third of the energy input to the engine is rejected to the engine cooling system. Increasing the output power of the engines will require either new or modified heat exchangers. To satisfy the increased cooling water requirements, new cooling water pumps will be required. Also the increased flow rate will result in the need for significant replacement of pipe, fittings, strainers, and valves.
- Lubrication Oil System – It is not anticipated that increasing the speed of the existing engines and the addition of a turbocharger will result in any modifications to the existing lubricating oil system. The lubrication oil system is suitable for the increase in engine capacity.
- Starting Air System – It is not anticipated that increasing the speed of the existing engines and the addition of a turbocharger will result in any modifications to the existing starting air system.
- Building Ventilation and Filtering – Combustion air inlet for each engine is located on the engine and any increase in inlet air temperature may result in reduced engine horsepower output. Approximately 6 to 8 percent of the fuel consumed by the engine is rejected to the surrounding room. Due to the increased output capacity of the engine, up to 65 percent additional heat load can be expected in the building. To maintain suitable inlet air temperature for the engines for proper operation of the engine and for the operators, additional supply and exhaust fans must be added. In addition, since the air into the building is required to be filtered, significant changes will be required to increase the filter surface area to handle the increased air flow rates.

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- Drive Shaft – Increasing the engine rating and increasing the engine drive speed will result in increased torque and stress on the drive shaft from the engine to the gear reducer and it will need to be replaced with a larger shaft.
- Gear Reducer – The existing Philadelphia right angle gear reducer horsepower rating is inadequate for any increase in engine rating. Most options also require a change of both engine speed and propeller speed resulting in a gear ratio change. This will require a total replacement of the gear reducer. In addition, for the maximum load options, the maximum down thrust from the propeller will require going to a liquid film type thrust bearing (Kingsbury) instead of the current anti-friction type bearings.
- Pump Shaft and Couplings – Most pumping options require increasing the impeller speed, power transmitted from the gear reducer to the propeller, and down thrust forces. The combination of all three increasing simultaneously results in higher combined shear stresses levels in the shafting. Therefore all options which include increasing engine rating will require replacement of the pump shaft. Since there are many machined parts in contact with the shafting including bearing supports, couplings, and stuffing box, this will require significant modification to the pump.
- Engine-Generators – Required increase in the size of the cooling pumps and the number of ventilation fans along with small increases in miscellaneous auxiliary system loads will result in a greater load on the existing engine-generators. Also, larger horsepower motors for the seepage pumps will increase loads on the engine-generators. For proper operation of the station, the replacement of the existing engine-generators with larger units will be required.
- Exhaust Emission Permits – Any modifications to the output capacity of the engines drives and engine-generators will result in increased emissions. This in turn requires a new Title 5 emission permit to be issued. This will result in additional cost as well as having a significant time impact. It has been made clear that new Title 5 permitting must be completed before any improvement contract regarding the engines can be issued.
- Submergence – Contact with ENSR, who conducted the hydraulic modeling, indicated that the pumping station suction tunnel and approach was model tested up to 1300 cfs at the design suction tunnel submergence during their “High Reynolds Number” test. ENSR projected that based on their observations from the “High Reynolds Number” test the pumping station suction tunnel and inlet should perform acceptably for the flow rates in excess of the 925 cfs design.
- Net Positive Suction Head, NPSH – The existing pumping units have an NPSH requirement at design head of approximately 15 feet. The margin of NPSH available to NPSH required at 925 cfs is approximately 2 to 1. The Hydraulic Institute Standards recommends a margin of 1.3 so there is considerable margin available. For the maximum modification, the propeller requires an NPSH of 18 feet which reduces the margin to 1.6 which is acceptable. If the pumping units were permitted to pump at maximum speed of the engine and minimum total dynamic head the flow rate will approach 1300 cfs per pump. At this flow, the margin drops to 1.0 and the propeller could experience cavitations. To prevent this, the pump speed can be controlled to

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prevent the pump from “running” out on its curve. In this way, the NPSH required can be controlled and the NPSH available will provide sufficient margin to meet the Hydraulic Institute requirements. This can be achieved by controlling the pump speed such that the maximum engine speed is proportional to the discharge pool level with the engines at 700 rpm at low discharge pool levels and at maximum speed of 900 rpm when the reservoir is full.

In evaluating the modification potential of Pumping Station G-370 and G-372, several alternative propellers were investigated related to staged increases in the engine horsepower ratings: The pump propellers were selected with: no changes to engine, increasing engine speed, and turbo-charging the engine.

The pumping units modifications investigated include changing the speed of the propeller, providing new propellers with different vane angles, or both.

These modifications are shown as Options A through F in Figure 1.

4.1.1 Option A – No Change

The characteristics of the pump performance curves for the type of propellers used in G-370 and G-372 is that the horsepower requirement increases with pumping head and decreasing flow rate. For this reason there is a limit to how high the existing pumps can pump before exceeding the capacity of the engines. For this option there are no changes considered to the Pumping Station and that water is diverted from the STA 3/4 Feed Canal into the reservoir up to the design water surface of the STA 3/4 Feed Canal. Above this level, the engines will be at or above the nameplate ratings of engines and can not be operated. Therefore up to the design water surface of the STA 3/4 Feed Canal water can be delivered to the STA 3/4 and to the reservoir. Above this elevation, water can only be delivered to STA 3/4.

4.1.2 Option B - New Propeller

This is a minimal impact option to the pumping station that would permit using the existing drive and mechanical systems but still allow pumping to the design reservoir elevation. For this option, the existing propellers are replaced with new propellers that pump to higher heads at lower flows. The proposed new propellers are essentially the same design as the existing propellers except that the vane angles have been adjusted. While the original propellers could provide 925 cfs each to the STA 3/4 Feed Canal Design Elevation, the new propeller will only provide approximately 740 cfs each. The new propeller will meet the original intended G-370 design flow of 725 cfs. At the design elevation of the reservoir, the capacity would significantly less than 725 cfs, but the existing engine and building systems could be operated without any changes.

4.1.3 Option C - Increase Engine and Pump Speed

The engines provided for the pumping station are rated at 720 rpm. However according to the manufacturer they can be operated at 900 rpm. By simply increasing the engine speed, the output power of the engines can be increased by about 25 percent permitting the pump propeller to operate at higher speed and therefore capable of pumping to higher head levels. When

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operating at low discharge heads, the engines can be reduced in speed to permit operation under the same conditions that they currently do now. The increased horsepower ratings of the engines will however increase the mechanical loads and stresses in the pump and drive train and will require replacement of the drive train from the engine to the propeller plus general upgrade to most auxiliary systems.

4.1.4 Option D - Increase Engine and Pump Speed and Replace Propeller

The current propeller is designed for peak efficiency at the lower heads. As a result, it has lower efficiency at the higher heads where the maximum horsepower is required. To increase the capacity of the station more, a new propeller design was investigated that increased efficiency at the maximum head conditions. This propeller design is basically the same design as the existing propeller with a new vane angle. This new propeller design permits the pumping station to pump more water at the design reservoir elevation for the same horsepower required in Option C. The engine, drive train, and auxiliary system upgrade will be the same as in Option C.

4.1.5 Option E - Increase Engine and Pump Speed and Turbo-Charge Engine

The engine supplier, Fairbanks Morse has indicated that the 9 cylinder engines at G-372 have a standard turbocharger option which can significantly increase horsepower. Fairbanks Morse does not have a standard turbocharger option for the 8 cylinder engines at G-370. However they have indicated that they could design and provide a turbo-charger that will fit the 8 cylinder engines. Since Fairbanks Morse does not have any experience with turbo-charging an 8 cylinder engine, the rated capability of the G-370 engine at 900 rpm and turbo-charged cannot be firmly established at this time. From communications with Fairbanks Morse, it is anticipated that the power boost of the engine with turbocharger is sufficient to pump the current design capacity of the station to the design water level of the reservoir. However there is not much margin between the horsepower required and the horsepower estimated by Fairbanks Morse. During detailed design, the maximum anticipated flow rates may need to be adjusted.

The increased horsepower will result in the replacement of most of the drive train components and the auxiliary systems. Variable speed controls will be provided for the engine so that at low pumping heads, the pumping units can operate at reduced speed in order to keep the pump from operating at excessive capacity which would result in problems with submergence, cavitation, and vibration. However while operating at low

speed and low head, the engines will be significantly under loaded, resulting in higher maintenance cost and significantly reducing the mean time between over-hauls. An additional concern with the turbo-charger is that it is an 'add-on' device to the engine which significantly modifies the operation of the engine. While the cost of the turbocharger itself might not be excessive, there will be significant risk on either SFWMD or the modifying contractor which either way will result in significant intangible costs to the SFWMD.

4.1.6 Option F - Increase Engine and Pump Speed, Turbo-Charge Engine, and Replace Propeller

Because of concerns over what the maximum horsepower capability of the engine would be, a different propeller design was investigated that would increase the efficiency at the higher reservoir levels resulting in higher pumping rates. This new propeller design would be similar to the existing propeller with a different vane angle. The increased horsepower will result in the replacement of most of the drive train components and the auxiliary systems. Variable speed

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operation will also be required to prevent operating at excessive flow rates at low reservoir levels. While this option permits pumping greater amounts of water, this propeller will have lower efficiencies through out the operating reservoir level range resulting in higher overall operating costs.

4.2 Capacity of New Northeast Pumping Station

Design wet and dry flow capacity needs for the new Northeast Pumping Station are shown on spreadsheet Figure 2 and graphically on Figures 3 and 4. The required capacity varies according to the canal capacity and the effective capacity for the existing G-370 pump station. The capacity shown presumes that water is available from either Lake Okeechobee or from the northeast EAA via the Cross canal. Two scenarios are presented; the first (Figure 3) is for unlimited velocity in the canal, the second (Figure 4) is for a 2.5 fps maximum velocity restriction. In the scenario with unlimited velocity in the canal, velocities reach a maximum rate of about 3.2 fps in one reach, with the velocity for most flow regimes much less than that. For both conditions, it was assumed that peak wet weather flowrates did not exceed $\frac{3}{4}$ " per 24 hour period for the local drainage area. This is consistent with average permitted agricultural discharge rates in this area.

4.3 Modifications to Pumping Station G-372 and Canal in Alternative 4

A cross section of the canal modifications is shown on Figure 5. For Alternative 4, the modifications required to Pumping Station G-372 would be similar for each option described for Pumping Station G-370, except that four pumps and engines would be modified. Also, the seepage pumps would need to be modified to pump into the higher water level in the discharge canal.

4.3.1 Civil Structural Modifications to Pumping Station G-370

The civil structural modifications to pumping station G-370 are shown on Figure 6.

When the A1 Reservoir is nearly full, the water surface will be above the pump discharge sill elevation resulting in backflow of water through the pumps when they are stopped. The improvements to pumping station G-370 shown on Figure 6 include flap gates on each pump discharge to prevent backflow of water through a pump when it is not operating. Also included is a gate structure divided into three sections, one for each pump, to allow accessing the flap gates for each pump individually for maintenance. Other improvements required include raising the level of the embankments on the discharge side of the pumping station and gate structures at the inlet to the A1 Reservoir and at the supply canal. Closing the gate structure at the supply canal and opening the gates at the reservoir inlet allow the pumping station to discharge into the reservoir. Closing the gates at the A1 Reservoir inlet and opening the gates at the supply canal allows the pump station to discharge to the supply canal. Opening gates at both structures would allow discharging water from the reservoir to the STA 3/4 supply canal. Modifications to the seepage pumps would also be required to permit them to pump into the discharge canal when water levels are high. An alternative to modifying the pumps would be a bypass culvert from the pump discharge to the STA 3/4 supply canal or the pump station suction canal. Discharging seepage to the STA 3/4 supply canal would have the advantage of sending the relatively clean seepage directly to the STA 3/4 treatment facility. However, construction of a bypass culvert would be significantly more expensive than modifying the pumps. Discharging seepage to the

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pump station suction canal would also be more costly than modifying the pumps and would also effectively reduce the overall capacity of the pumping station.

Another alternative, which is a slight variation on the above plan, was also investigated. This involved constructing a larger structure on the pump station discharge with a concrete flume to the inlet to the A1 Reservoir. The structure includes flap gates and shut off gates on each pump discharge to prevent the backflow of water when pumping to a nearly full A1 Reservoir and shutoff gates also on each pump discharge to direct water to the supply canal. A gate structure would also be provided at the inlet to the A1 Reservoir. The advantages of this arrangement is that the pumps could be started at the discharge level of the STA 3/4 supply canal rather than the level of the reservoir. Early in the analysis of the pumping units it was expected that starting the pumps at a lower discharge level would be necessary to limit the required output of the engines driving the pumps. It was later found that limiting the starting head for the pumps was not necessary. This arrangement would not have required modifying the seepage pumps because they could continue to pump to the discharge canal at current elevations. This alternative would require significantly more construction to take place under wet conditions in the discharge canal and was more costly. Because it was not necessary to start the pumps at a lowered discharge head and due to the cost, this alternative was dropped.

The plan selected for controlling the backflow of water through the pumps at high A1 Reservoir levels includes a structure on the pump station discharge containing flap gates and a gate structure downstream of the flap gates to allow isolating the flap gates for maintenance. The embankments on the discharge side of the pumping station will be raised to direct the pumping station discharge to the A1 Reservoir. These improvements consist of a concrete flood wall constructed from the southwest corner of pumping station G-370 across the top of the discharge canal embankment for a distance of approximately 400 feet, a concrete wall from the northwest corner of the pumping station along the west edge of the parking lot, and an embankment across the STA 3/4 feeder canal. The top of the new walls and the embankment will be at approximately elevation 24.6 and will direct the pumping station discharge flows to new gate structures.

Two new gate structures will control the flow of water to the A1 Reservoir and to the STA 3/4 feeder canal. The reservoir gate structure will be located in the reservoir embankment and when closed, the gates will act as the reservoir wall. The STA 3/4 feeder canal gate structure would allow control of flow to the STA 3/4 feeder canal. When the gates are closed, pumping station G-370 discharge flow would be directed through the reservoir gate structure to the A1 Reservoir and when opened, the flow directed to the STA 3/4 feeder canal. These gates would also enable water from the reservoir to flow in the reverse direction through the reservoir gate structure and be directed to the STA 3/4 feeder canal. The STA 3/4 feeder canal gate structure is shown constructed outside the feeder canal. As an option, it could also be constructed in the canal if the feeder canal can be removed from service during construction.

Modifications to the seepage pumps include installation of new check valves and isolation valves on the discharge of each pump to prevent backflow through the pumps when water levels in the discharge canal are high. Pump motors and the adjustable speed drives will be replaced to enable the pumps to operate at the higher head. The opening in the wall at the pump discharges will be closed and a room created for the new valves above the pump discharge pit.

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4.4 New Booster Pumping Stations

Alternatives 5, 6, 7 and 5A include booster pumping stations to pump water from the STA 3/4 supply canal into the A1 Reservoir. The capacities of the booster pumping stations are shown on Figures 12, 13, 14, and 18. The arrangement of the pumping stations and the pump discharge head would be similar to G-370 and G-372.

5. DISCUSSION OF ALTERNATIVES

The cost information in Tables 1 and 2 shows the total cost of each of the alternatives and the options for modifying pump stations G-370 and G-372. Costs include the new Northeast pumping station and the booster pumping stations. Advantages and disadvantages of each alternative are listed in Table 3.

Figure 7 shows the total pumping capacities for flood control and the capacities to pump to Reservoir A-1 water surface level 20.6 as well as the cost per cfs for these associated capacities.

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TABLES

Table 1 Pumping and Discharge Facilities Costs – Alternatives 1 through 7

7/25/2005

All Costs in Million Dollars

Alternative	Option	NE Pumping Station	G-370 Modifications		G-372 Modifications		Booster Pumping Sta.	Subtotal	Indirect Costs	Total
			Mech. & Misc. Modif.	Civil	Mech. & Misc. Modif.	Civil				
1		40.0	-	3.0	-	5.9		48.8	18.2	67.0
2		40.0	-	4.1	-	5.3		49.4	18.6	68.0
3	B	40.4	2.1	16.3	-	5.3		64.0	28.6	92.6
	C	32.3	6.0	16.3	-	5.3		59.8	29.0	88.8
	D	27.5	6.8	16.3	-	5.3		55.9	28.1	84.0
	E	18.2	6.9	16.3	-	5.3		46.6	25.3	72.0
	F	18.2	7.7	16.3	-	5.3		47.5	26.0	73.4
4	B	40.4	2.1	16.3	2.5	40.0		101.2	54.7	155.9
	C	32.3	6.0	16.3	7.7	40.0		102.2	58.6	160.9
	D	27.5	6.8	16.3	8.9	40.0		99.4	58.6	158.1
	E	18.2	6.9	16.3	8.9	40.0		90.2	55.9	146.1
	F	18.2	7.7	16.3	10.1	40.0		92.2	57.3	149.5
5	B	40.4	2.1	16.3	-	5.3	37.0	101.0	54.5	155.5
	C	32.3	6.0	16.3	-	5.3	37.0	96.8	54.9	151.7
	D	27.5	6.8	16.3	-	5.3	37.0	92.9	54.0	146.9
	E	18.2	6.9	16.3	-	5.3	37.0	83.6	51.2	134.9
	F	18.2	7.7	16.3	-	5.3	37.0	84.5	51.9	136.3
6		-	-	3.0	-	5.9	43.5	52.3	36.6	89.0
7		18.2	-	3.0	-	5.9	43.5	70.5	42.1	112.6

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Table 2 Pumping and Discharge Facilities Costs – Alternatives 2A through 5A

7/25/2005

All Costs in Million Dollars

Alternative	Option	NE Pumping Station	G-370 Modifications		G-372 Modifications		Booster Pumping Sta.	Subtotal	Indirect Costs	Total
			Mech. & Misc. Modif.	Civil	Mech. & Misc. Modif.	Civil				
2A		40.0	-	12.2	-	17.5		69.6	32.7	102.3
3A	B	40.4	2.1	19.2	-	17.5		79.1	39.2	118.3
	C	32.3	6.0	19.2	-	17.5		74.9	39.5	114.4
	D	27.5	6.8	19.2	-	17.5		71.0	38.7	109.7
	E	18.2	6.9	19.2	-	17.5		61.7	35.9	97.6
	F	18.2	7.7	19.2	-	17.5		62.6	36.5	99.1
4A	B	40.4	2.1	19.2	2.5	45.9		110.0	60.9	170.9
	C	32.3	6.0	19.2	7.7	45.9		111.1	64.8	175.9
	D	27.5	6.8	19.2	8.9	45.9		108.3	64.8	173.1
	E	18.2	6.9	19.2	8.9	45.9		99.0	62.1	161.1
	F	18.2	7.7	19.2	10.1	45.9		101.1	63.5	164.5
5A	B	40.4	2.1	19.2	-	12.2	37.0	110.8	61.4	172.2
	C	32.3	6.0	19.2	-	12.2	37.0	106.6	61.7	168.3
	D	27.5	6.8	19.2	-	12.2	37.0	102.7	60.9	163.6
	E	18.2	6.9	19.2	-	12.2	37.0	93.4	58.1	151.5
	F	18.2	7.7	19.2	-	12.2	37.0	94.3	58.7	153.0

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Table 3 Pumping and Discharge Facilities Alternative Advantages and Disadvantages

Alternative	Advantages	Disadvantages
1	<ul style="list-style-type: none"> Increased pumping capacity from North New River Canal; increased flood protection capability. No change to existing pump stations G-370 and G-372, therefore no associated cost, no operational impact during construction. 	<ul style="list-style-type: none"> G-370 and G-372 service is limited to pumping to the STA; pumping capacity into reservoir is limited to capacity of the NE Pump Station.
2 & 2A	<ul style="list-style-type: none"> Increased pumping capacity from North New River Canal; increased flood protection capability. No change to existing pump stations G-370 and G-372, therefore no associated cost; no operational impact during construction. Increased capacity to pump water into reservoir up to El 16.6. 	<ul style="list-style-type: none"> Pumping capacity into reservoir is limited to capacity of the NE Pump Station when water elevation exceeds 16.6. Increased operator attention required due to change in operation at water elevation 16.6.
3 & 3A	<ul style="list-style-type: none"> Increased pumping capacity from North New River Canal; increased flood protection capability. Provides capability to pump flow from G-372 to reservoir up to El 16.6. 	<ul style="list-style-type: none"> Requires modification to G-370 to allow pumping directly to the reservoir; costly. Increased degree of construction difficulty; need to maintain G-370 in operation during conversion. Pumping capacity into reservoir is limited to capacity of the NE Pump Station and G-370 when water elevation exceeds 16.6. Increased operator attention required.
4 & 4A	<ul style="list-style-type: none"> Increased pumping capacity from North New River Canal; increased flood protection capability. All flow from G-370 and G-372 can be pumped into reservoir. Maximizes amount of flow that can be pumped from both North New River and Miami Canals into the reservoir. Simple operation. 	<ul style="list-style-type: none"> Requires modification to G-370 to allow pumping directly to the reservoir; costly. Requires modification to G-372 and adjacent feeder canal to allow pumping directly to the reservoir; costly. Increased degree of construction difficulty; need to maintain G-370 and G-372 in operation during conversion.

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Alternative	Advantages	Disadvantages
5 & 5A	<ul style="list-style-type: none"> Increased pumping capacity from North New River Canal; increased flood protection capability. All flow from G-370 and G-372 can be pumped into reservoir. Maximizes amount of flow that can be pumped from both North New River and Miami Canals into the reservoir. Simple operation. 	<ul style="list-style-type: none"> Requires modification to G-370 to allow pumping directly to the reservoir; costly. Requires addition of another pump station along STA supply canal; costly. Increased degree of construction difficulty need to maintain G-370 in operation during conversion.
6	<ul style="list-style-type: none"> No change to existing Pumping Stations G-370 and G-372, therefore no associated cost, no operational impacts during construction. 	<ul style="list-style-type: none"> No additional flood protection capability. Cannot modify to pump all flow into the reservoir
7	<ul style="list-style-type: none"> No change to existing Pumping Stations G-370 and G-372, therefore no associated cost, no operational impacts during construction 	<ul style="list-style-type: none"> Limited increase in flood protection capability Can not modify to pump all flow into the reservoir


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FIGURES

Figure 1 Pumping Station G-370 Pump/Engine/Propeller/Drive Modification Options

PUMPING STATION G-370									
PUMP/ENGINE/PROPELLER/DRIVE MODIFICATION OPTIONS									
FOR ALTER- NATIVE NUMBER	OPTION	PUMPS	ENGINE				MECHANICAL SYSTEM	PUMP CAPACITY CFS	PUMP STA CAPACITY CFS
		REPLACE PROPELLER	H.P.	RPM	ADD TURBO	REPLACE GEAR REDUCER	UPGRADE REQUIRED		
1, 2, 2A	A	-	1300	720	-	-	NO	780* 0**	2340* 0**
3, 4, 5 3A, 4A, 5A	B	YES	1300	720	-	-	NO	340	1020
3, 4, 5 3A, 4A, 5A	C	-	1600	900	-	YES	YES	620	1860
3, 4, 5 3A, 4A, 5A	D	YES	1600	900	-	YES	YES	740	2220
3, 4, 5 3A, 4A, 5A	E	-	2000	900	YES	YES	YES	925	2775
3, 4, 5 3A, 4A, 5A	F	YES	1950	900	YES	YES	YES	925	2775
6		NEW PS 6475							6475
7		NEW PS 6475***							7475***

*UP TO ELEVATION 16.6 FEET **ABOVE ELEVATION 16.6 FEET
 ***NEW PUMP STATION 6475 CFS + NE PUMP STATION 1000 CFS


		 BLACK & VEATCH Corporation			
		PROJECT 141733		PUMP STATION G-370 MODIFICATION OPTIONS	
DATE	REVISION OR ISSUE	NO.	BY		

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Figure 2 Northeast Pumping Station + G-370 Pumping Station Wet and Dry Capacities into Reservoir A-1

<u>NORTHEAST PUMPING STATION + G-370 PUMPING STATION</u>										
<u>WET AND DRY CAPACITIES INTO RESERVOIR A-1</u>										
ALTER-NATIVE	G-370 PS		NORTHEAST PUMPING STATION				TOTAL FLOW NORTHEAST PS + G-370 PS			
	OPTION	FLOWRATE	NO MAX VELOCITY		MAX VEL = 2.5 FPS		NO MAX VELOCITY		MAX VEL = 2.5 FPS	
			WET	DRY	WET	DRY	WET	DRY	WET	DRY
1	A	0	3200	3700	3625	2900	3200	3700	3625	2900
2 & 2A	A	2350**	3200	3700	3625	2900	3200	3700	3625	2900
3, 4, 5 3A, 4A, 5A	B	1020	3800	2500	3700	1900	4820	3520	3720	2920
3, 4, 5 3A, 4A, 5A	C	1860	2800	1400	2000	1300	4660	3260	3860	3160
3, 4, 5 3A, 4A, 5A	D	2220	2000	700	1700	700	4220	2920	3920	2920
3, 4, 5 3A, 4A, 5A	E	2775	1000	500*	1600*	500	3775	2850	3950	2850
3, 4, 5 3A, 4A, 5A	F	2775	1000	500*	1600*	500				
6	-	NEW PS 6475	-	NEW PUMP STATION						6475
7	-	NEW PS 6475	1000	NEW PS + NORTHEAST PS						7475

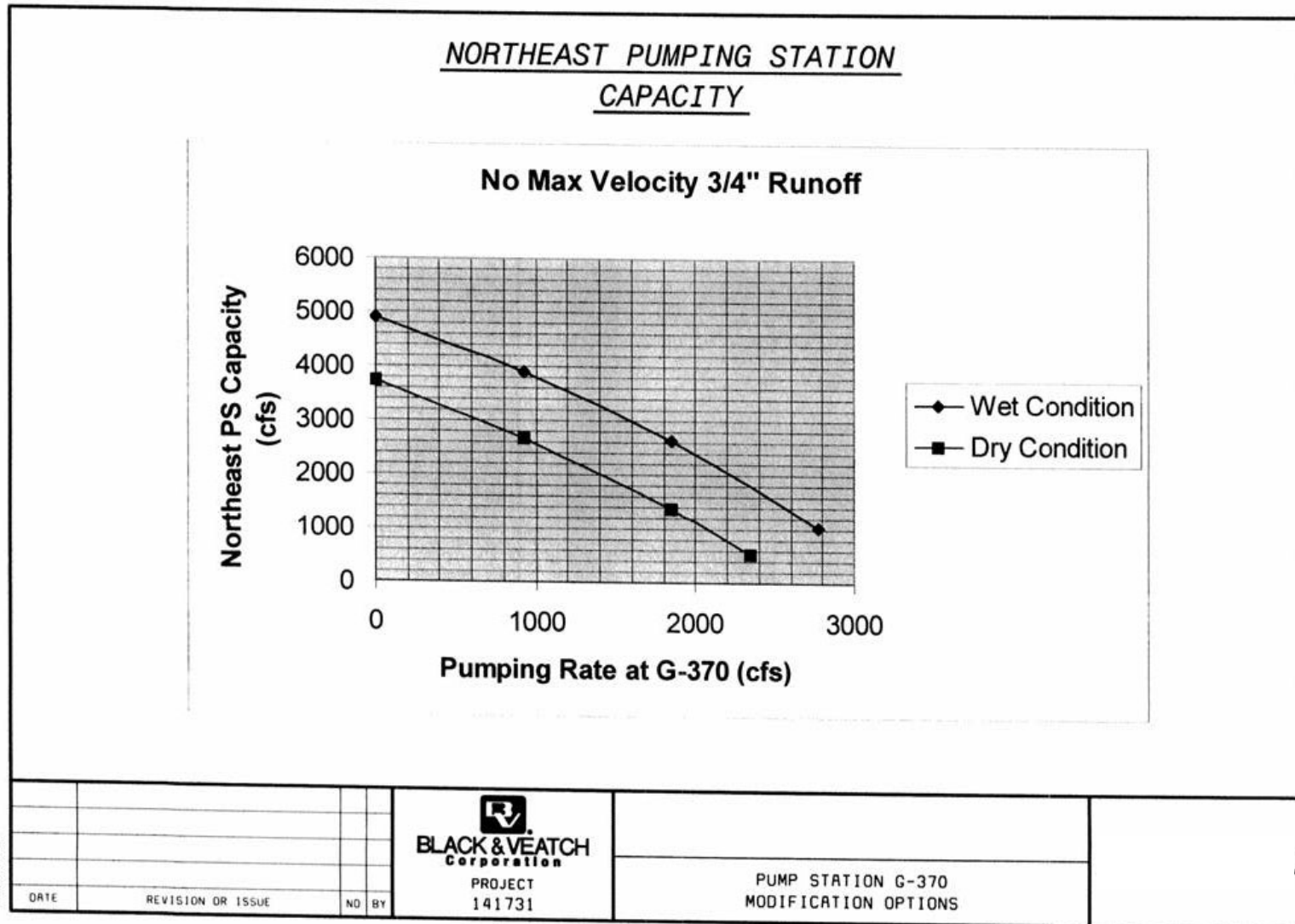
* FLOW = 2350 CFS @ G-370 ** UP TO EL 16.6
*** HIGHER FLOW RATE UP TO EL 16.6, LOWER FLOW RATE FROM 16.6 TO 20.6

R30006 P30006				 BLACK & VEATCH Corporation PROJECT 141731	PUMP STATION G-370 MODIFICATION OPTIONS	
	DATE	REVISION OR ISSUE	NO			

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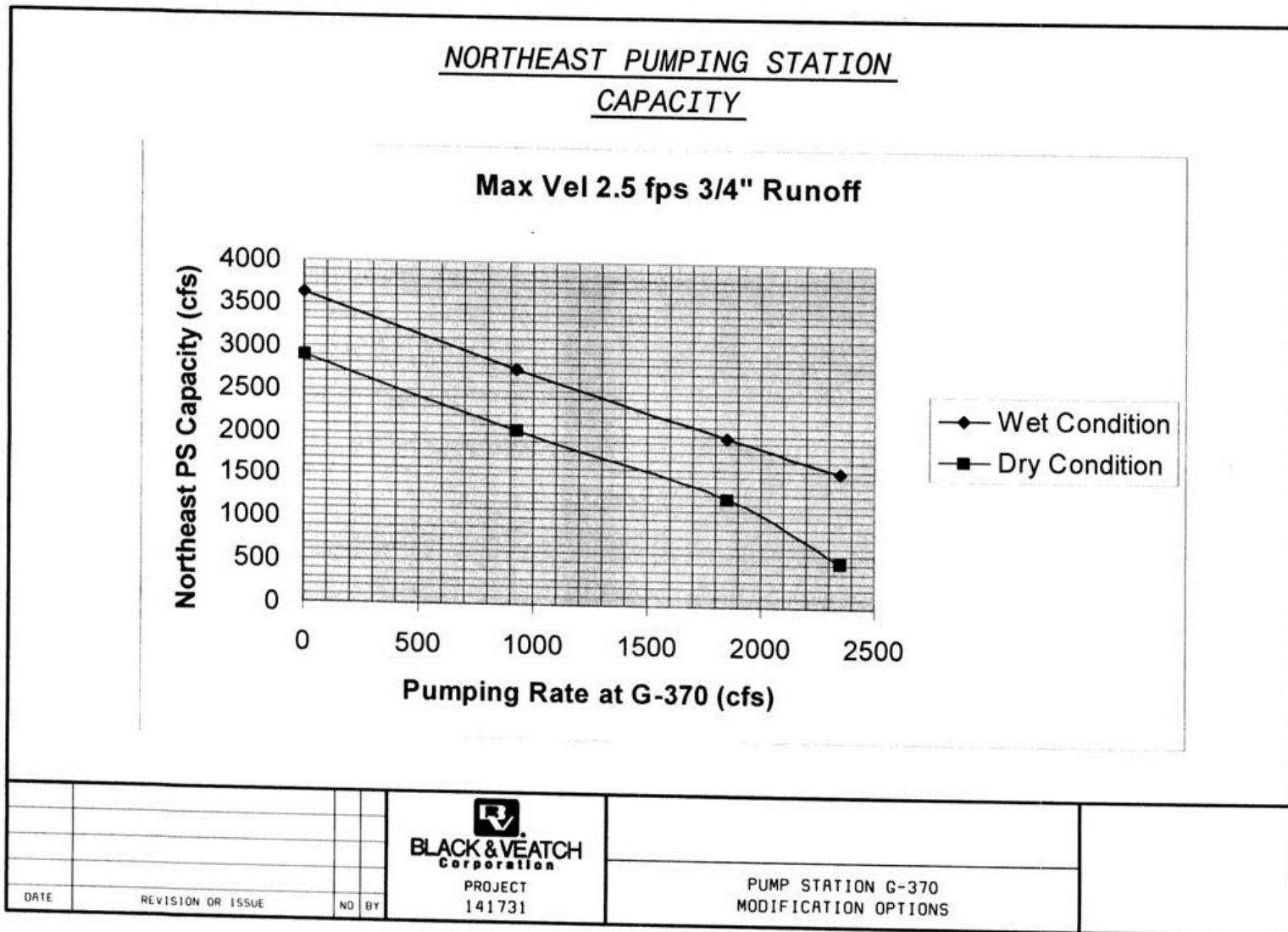
Figure 3

Northeast Pumping Station Capacity – No Max Velocity 3/4" Runoff



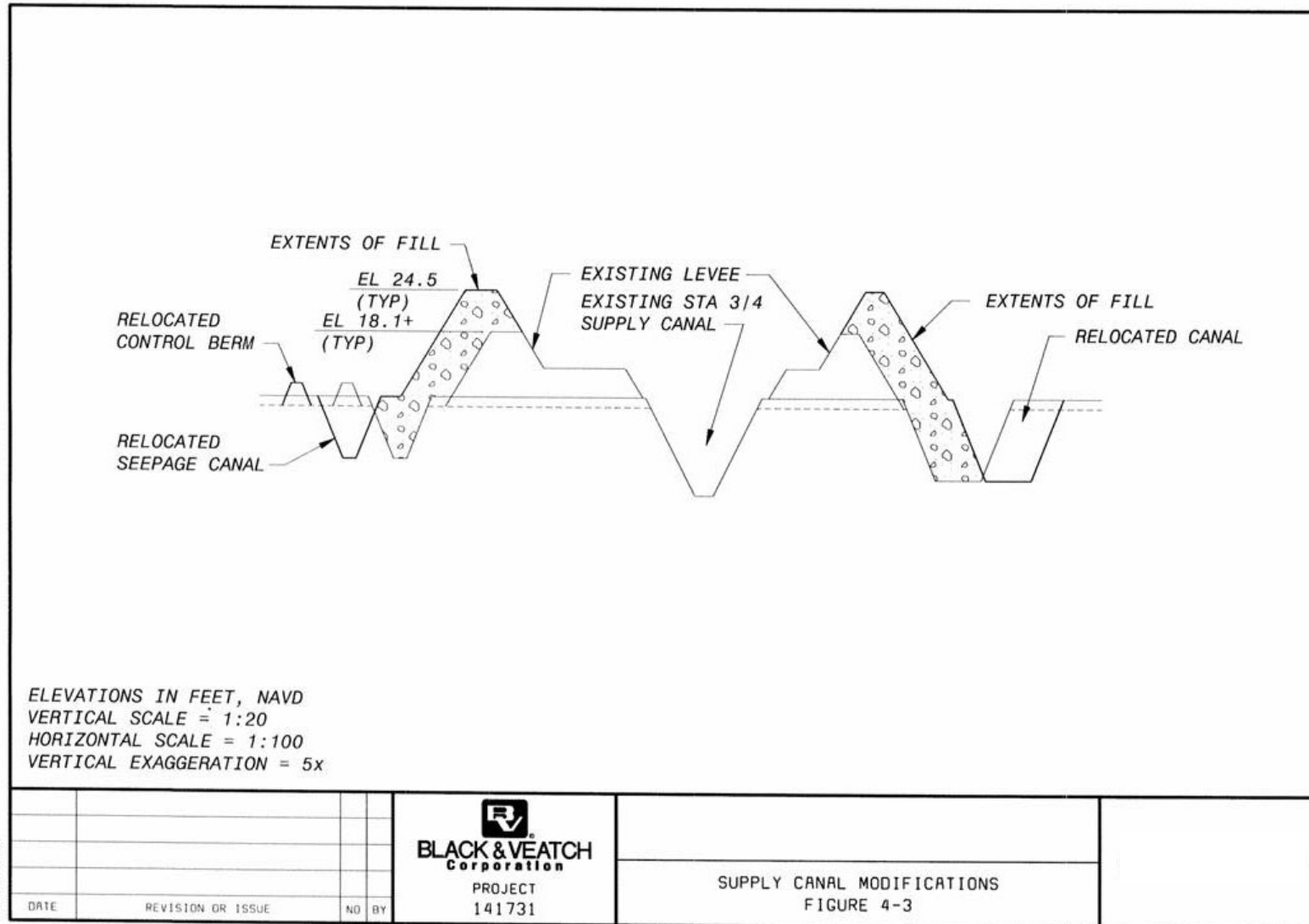
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Figure 4 Northeast Pumping Station Capacity –Max Velocity 2.5 fps 3/4” Runoff



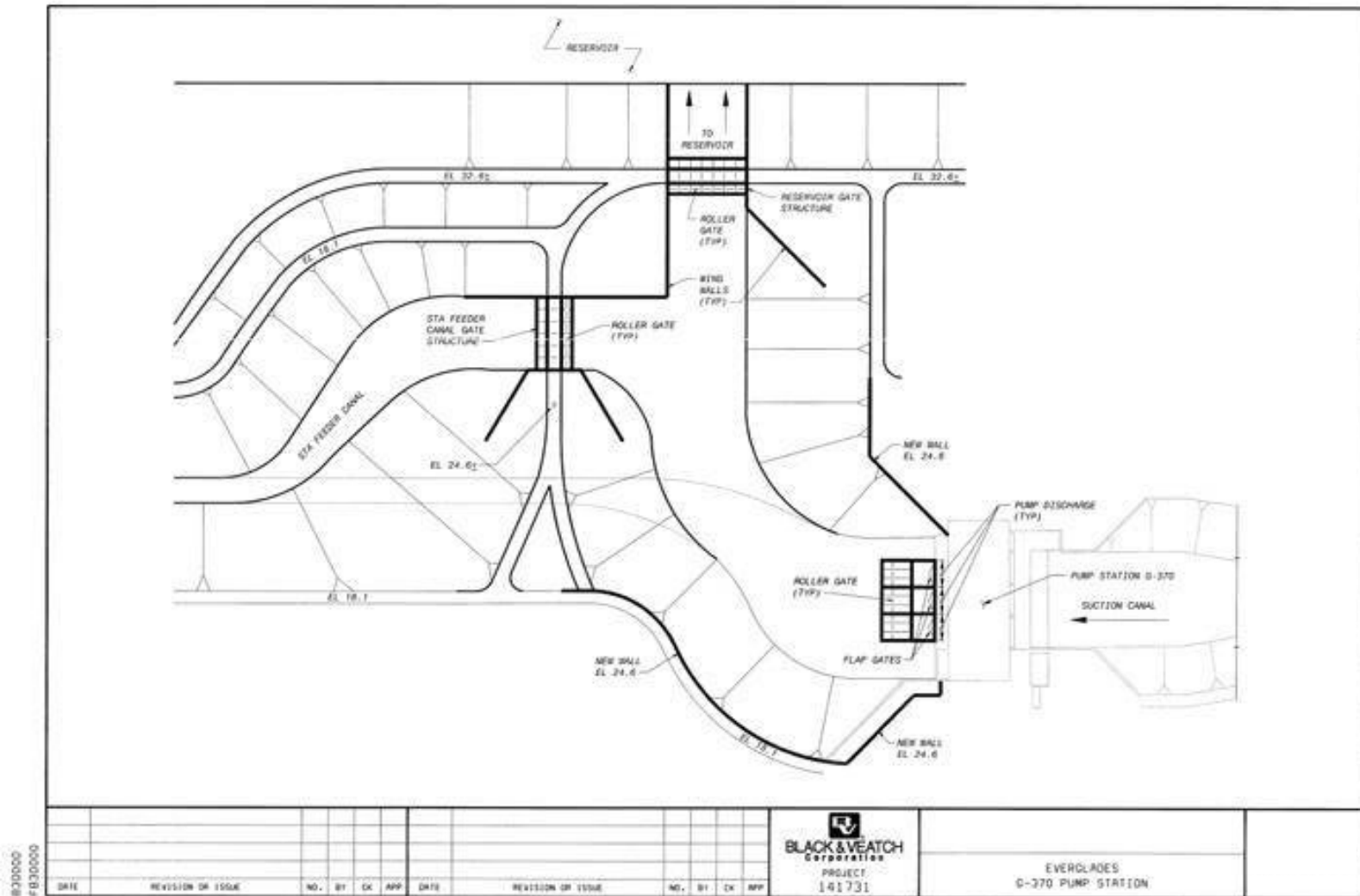
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Figure 5 Supply Canal Modifications



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Figure 6 Everglades G-370 Pump Station



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Figure 7 Pumping Capacity Summary

PUMPING CAPACITY SUMMARY TO RESERVOIR A-1 AND CAPACITY TO ELEVATION 20.6						
		NE PUMP STA	PUMP STA 370	PUMP STA 372	TOTAL CAPACITY	CAPACITY TO RESERVOIR A1 EL 20.6
1	-	3200	2775	3700	9675	3200
2 AND 2A	-	3200	2775	3700	9675	3200
3 AND 3A	B	3800	1020	3700	8520	4820
	C	2600	1860	3700	8160	4460
	D	2000	2220	3700	7920	4220
	E&F	1000	2775	3700	7475	3775
4 AND 4A	B	3000	1020	1368	6188	4820
	C	2600	1860	2480	6940	4460
	D	2000	2220	2960	7180	4220
	E&F	2000	2775	3700	7475	3775
5 AND 5A	B	3800	1020	3700	8520	4820
	C	2600	1860	3700	8160	4460
	D	2000	2220	3700	7920	4220
	E&F	1000	2775	3700	7475	3775
6	-	0	NEW PS 6475	-	6475	6475
7	-	1000	NEW PS 6475	-	7475	7475

R30006 FR30006					 BLACK & VEATCH Corporation PROJECT 141731	PUMP STATION G-370 PUMPING CAPACITY SUMMARY	
	DATE	REVISION OR ISSUE	NO	BY			

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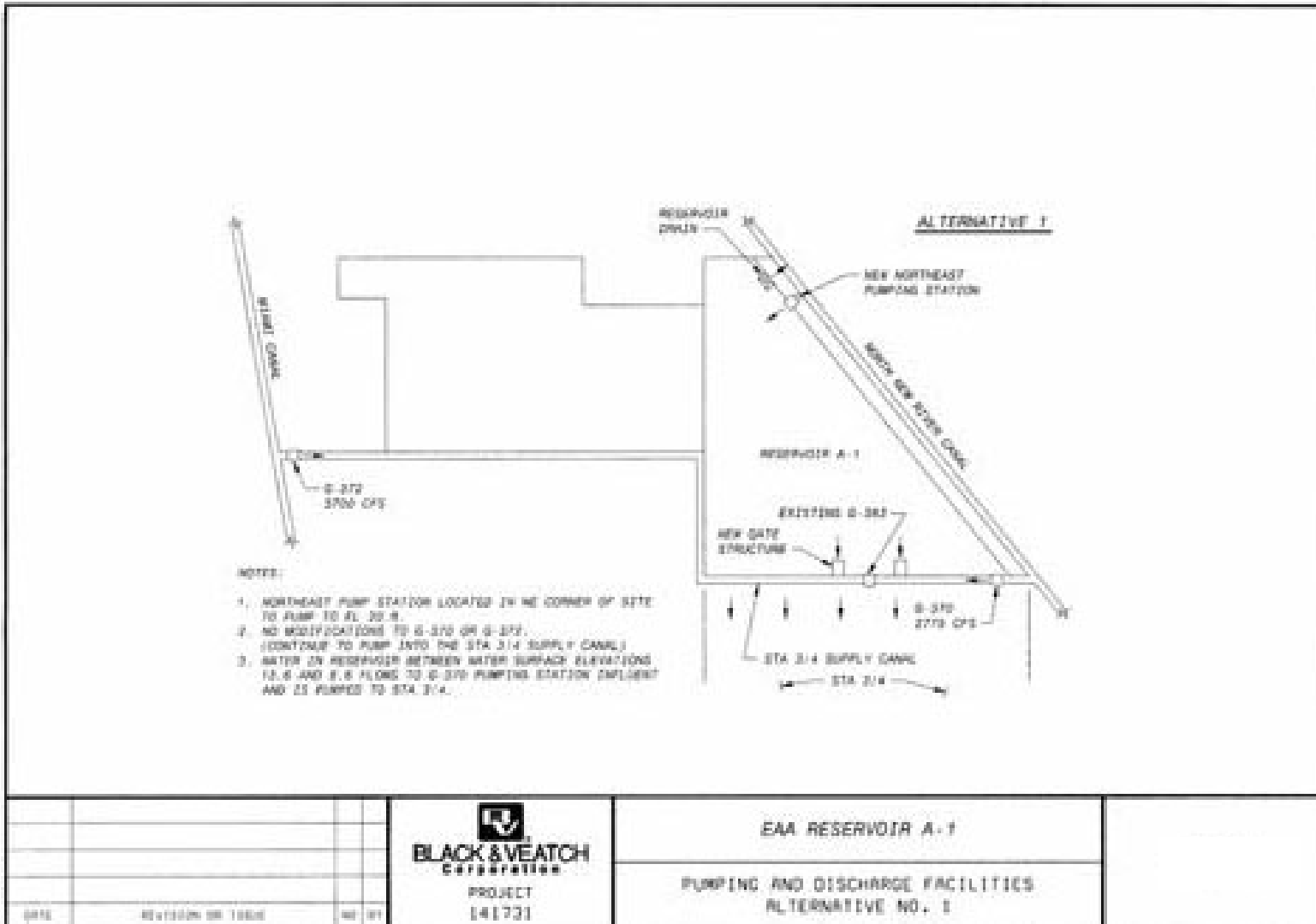
Alternative	Option	Total Cost Million \$	Total Pumping Capacity Cfs	Total Pumping Capacity Cost Per Cfs \$	Capacity To El 20.6 Cfs	Total Cost Per Cfs To El 20.6 \$
1	-	67.00	9675	6925	9675	6925
2	-	68.00	9675	7028	9675	7028
2A	-	102.30	9675	10573	9675	10573
3	B	92.65	8520	10874	4820	19222
	C	88.77	8160	10879	4460	19904
	D	84.00	7920	10606	4220	19905
	E	71.96	7475	9627	3775	19062
	F	73.43	7475	9822	3775	19452
3A	B	118.31	8520	13886	8520	13886
	C	114.44	8160	14025	8160	14025
	D	109.66	7920	13845	7920	13845
	E	97.62	7475	13060	7475	13060
	F	99.09	7475	13256	7475	13256
4	B	155.90	6188	25194	6188	25194
	C	160.89	6940	23183	6940	23183
	D	158.06	7180	22014	7180	22014
	E	146.09	7475	19544	7475	19544
	F	149.51	7475	20001	7475	20001
4A	B	170.90	6188	27618	6188	27618
	C	175.89	6940	25344	6940	25344
	D	173.06	7180	24103	7180	24103
	E	161.10	7475	21551	7475	21551
	F	164.51	7475	22008	7475	22008
5	B	155.55	8520	18257	8520	18257
	C	151.67	8160	18587	8160	18587

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Alternative	Option	Total Cost Million \$	Total Pumping Capacity Cfs	Total Pumping Capacity Cost Per Cfs \$	Capacity To El 20.6 Cfs	Total Cost Per Cfs To El 20.6 \$
	D	146.90	7920	18548	7920	18548
	E	134.86	7475	18041	7475	18041
	F	136.63	7475	18278	7475	18278
5A	B	172.21	8520	20212	8520	20212
	C	168.33	8160	20629	8160	20629
	D	163.56	7920	20651	7920	20651
	E	151.52	7475	20270	7475	20270
	F	152.99	7475	20467	7475	20467
6	-	88.95	6475	13737	6475	13737
7	-	112.61	7475	15065	7475	15065

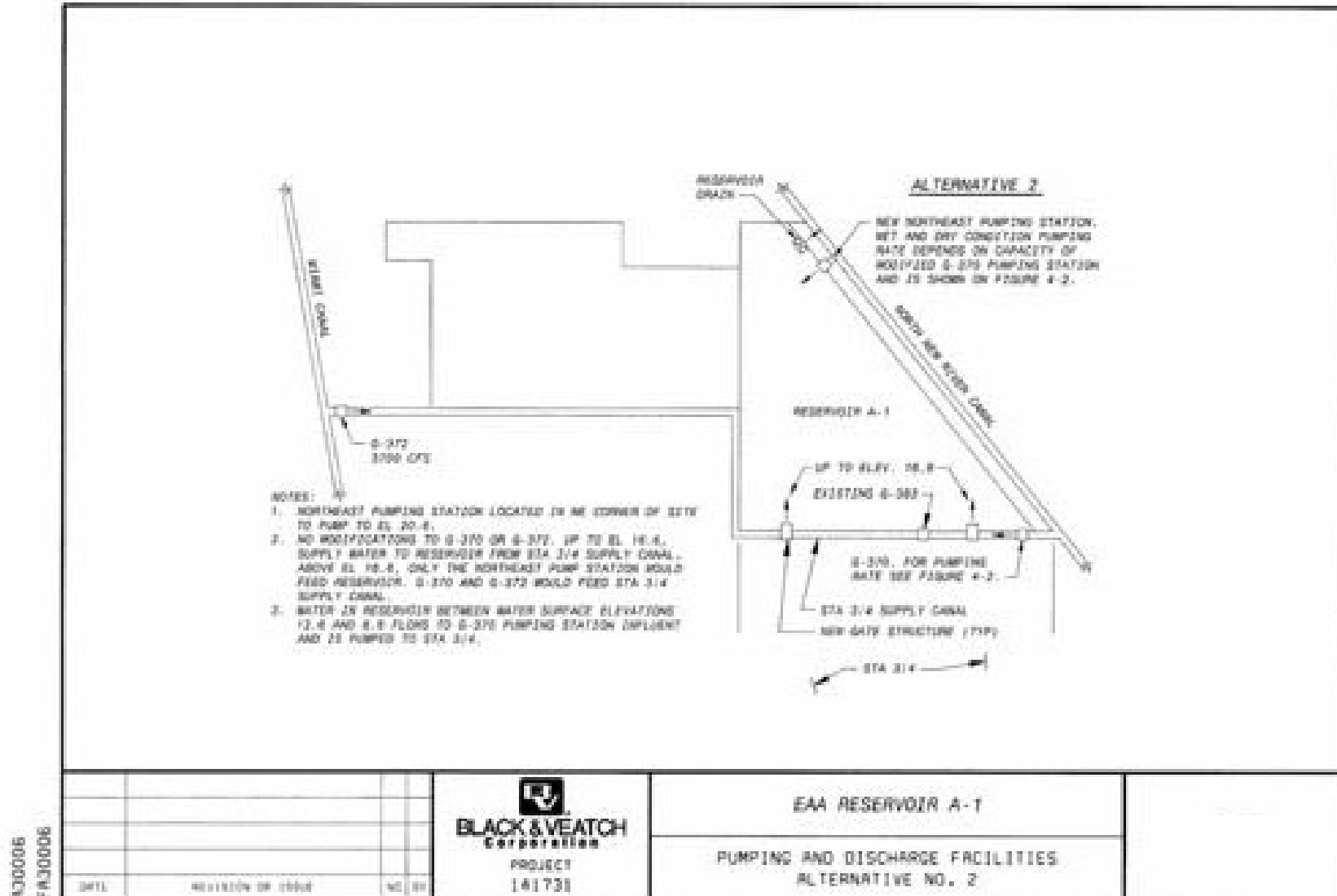
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Figure 8 Pumping and Discharge Facilities Alternative No. 1



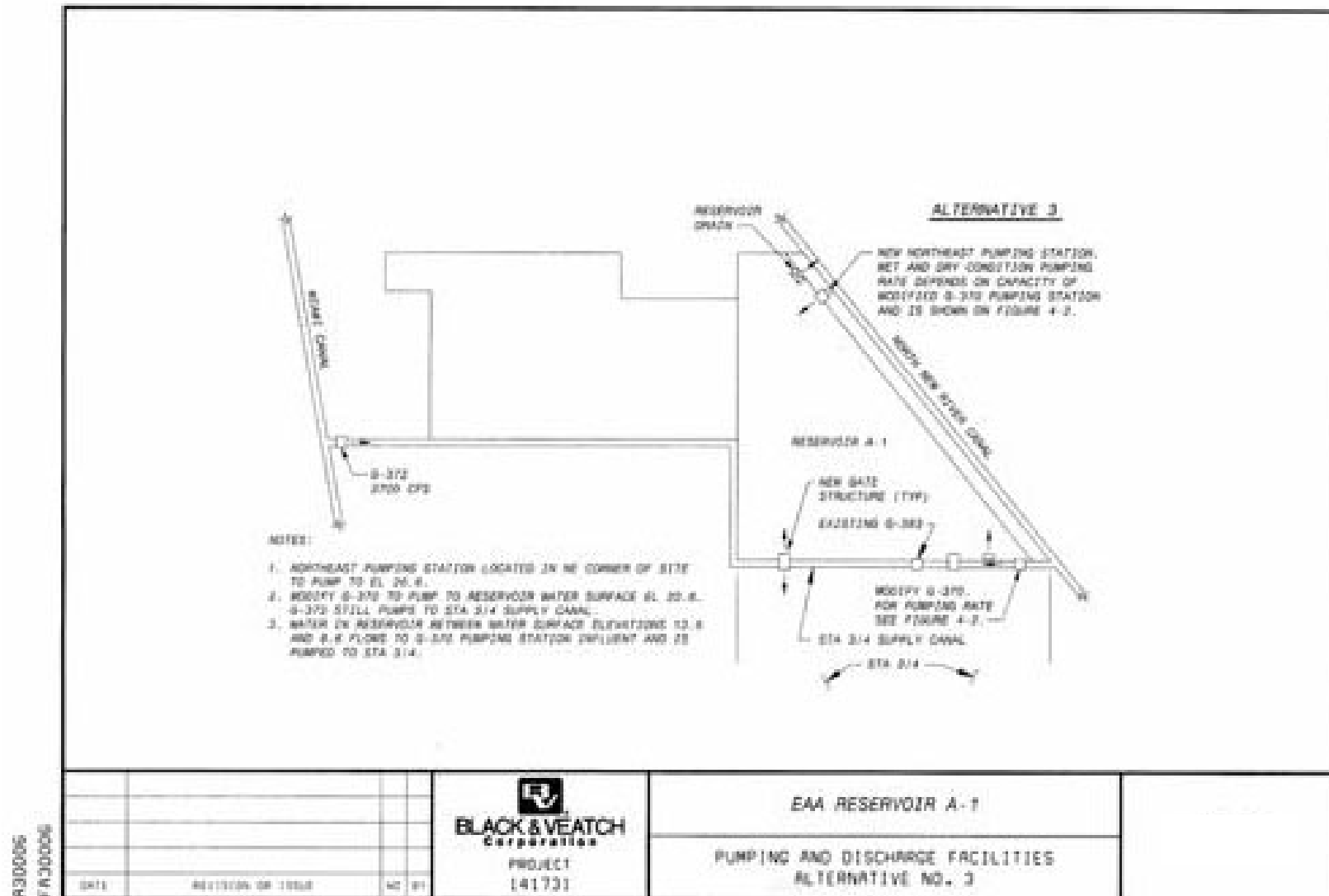
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Figure 9 Pumping and Discharge Facilities Alternative No. 2



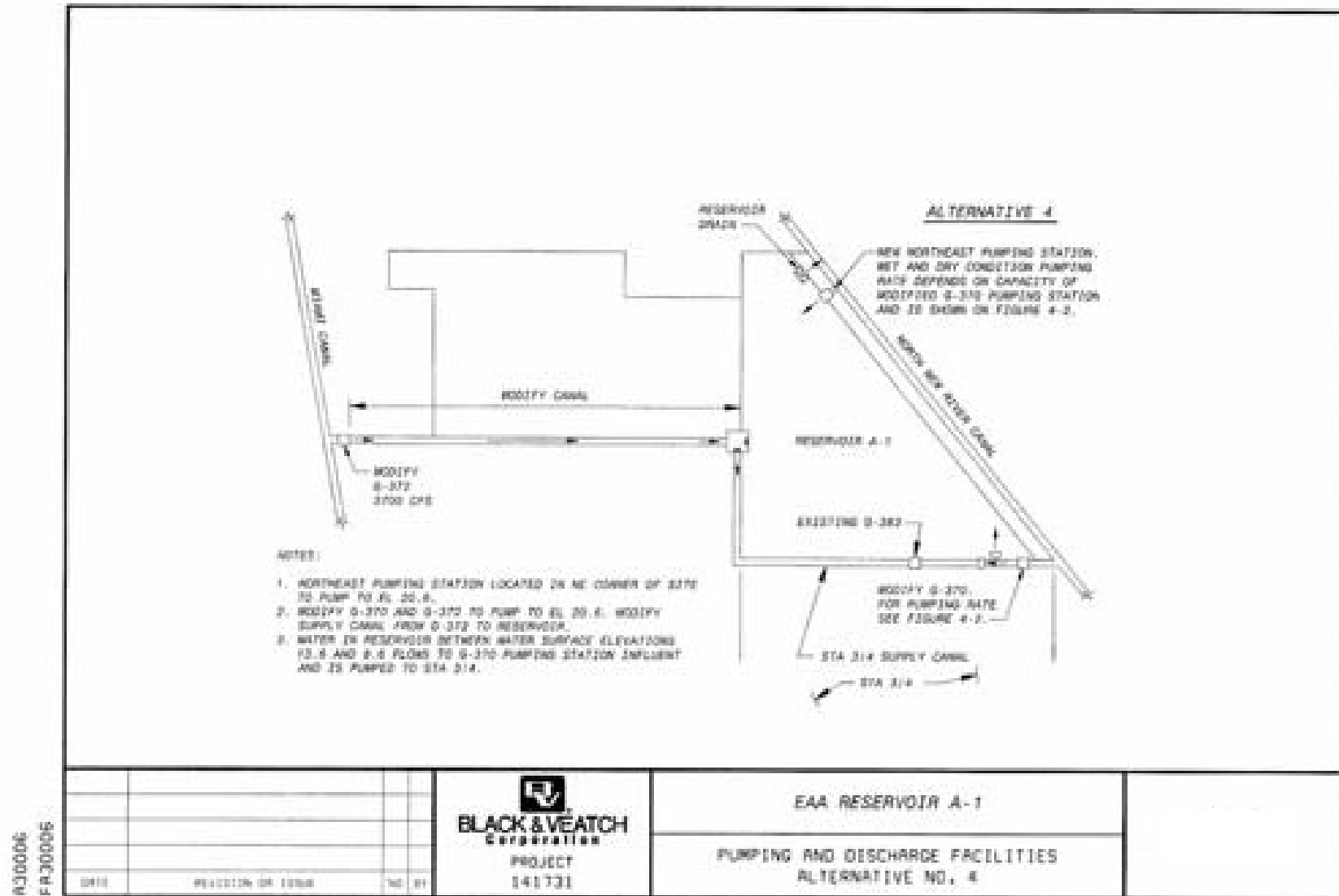
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Figure 10 Pumping and Discharge Facilities Alternative No. 3



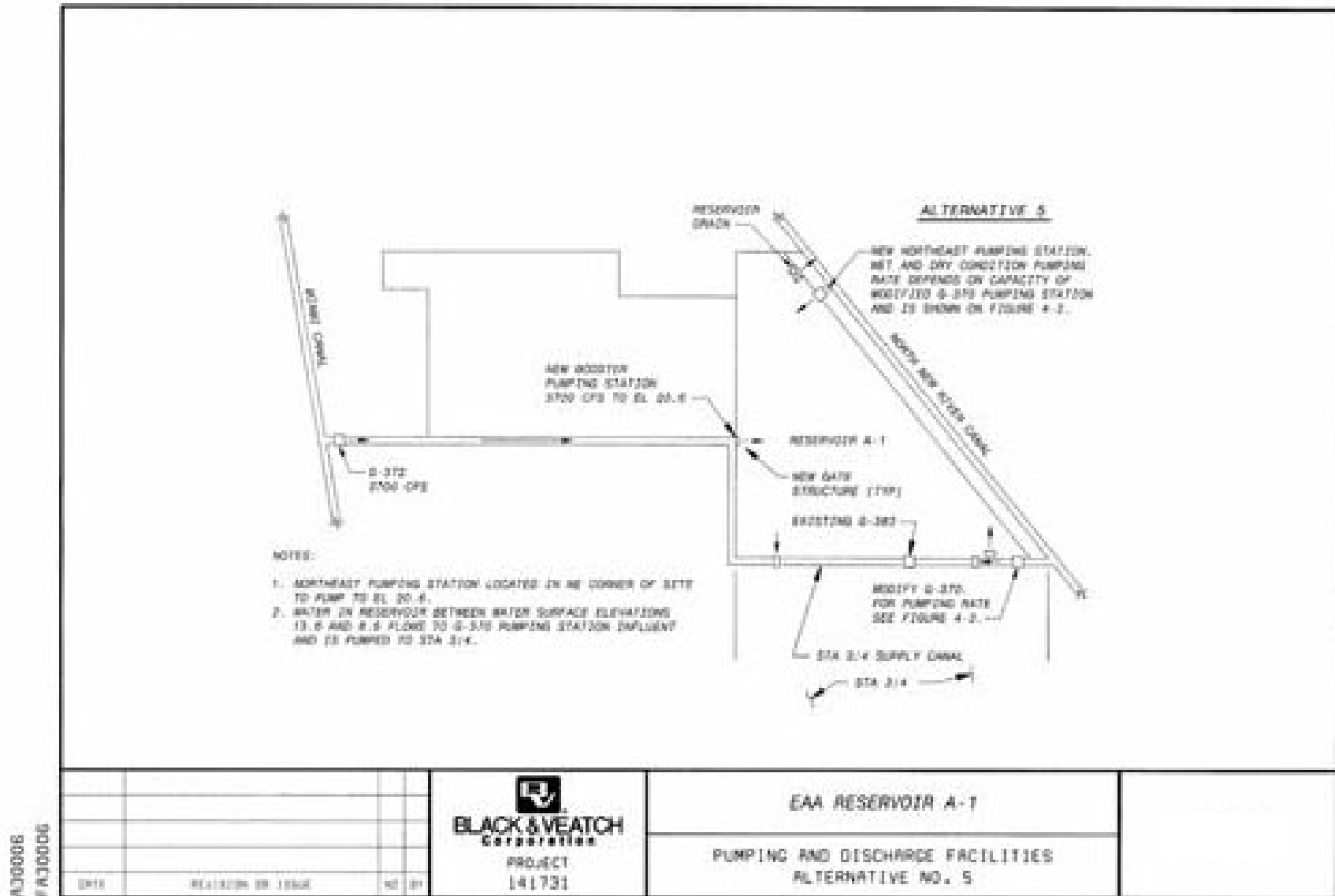
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Figure 11 Pumping and Discharge Facilities Alternative No. 4



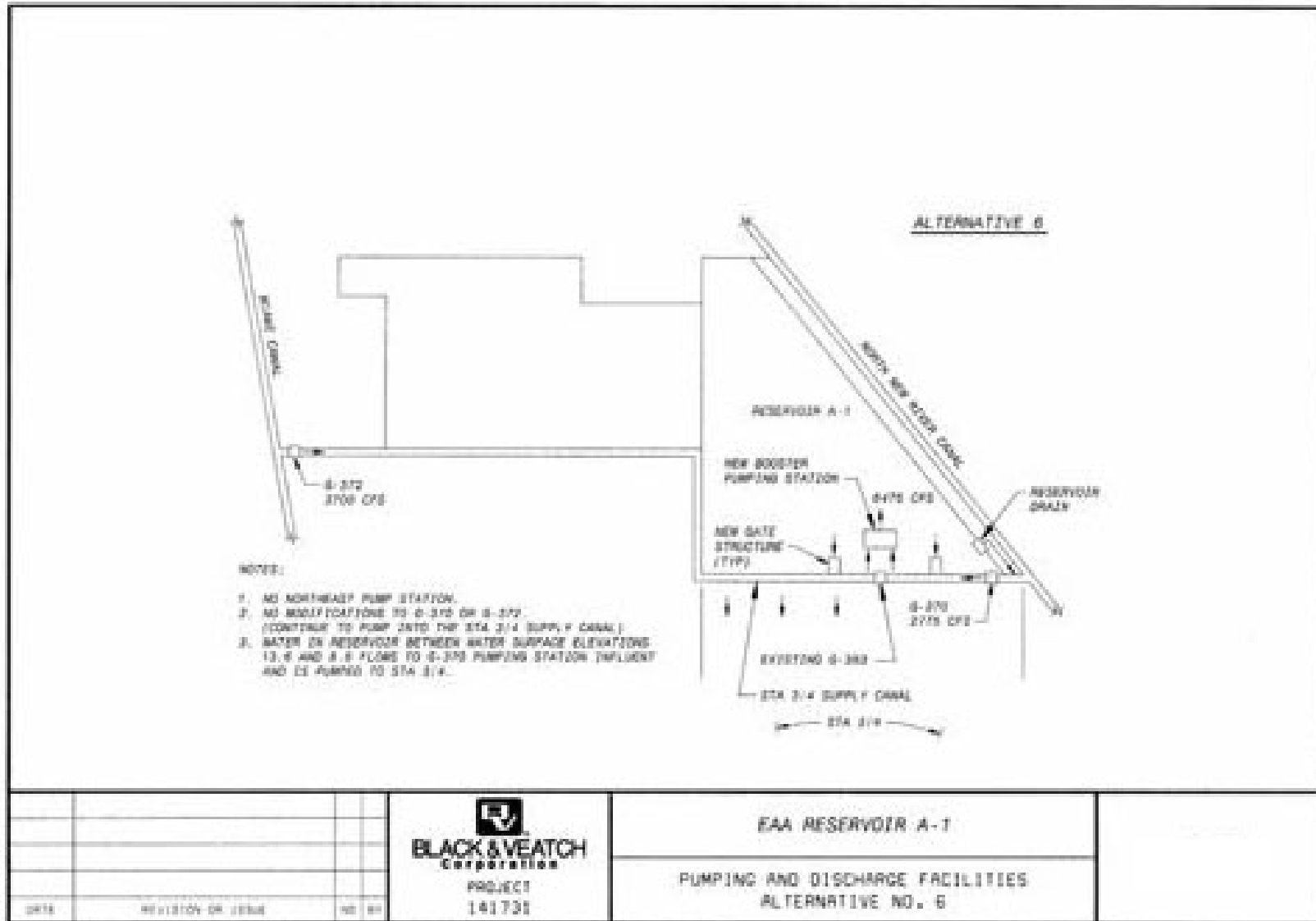
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Figure 12 Pumping and Discharge Facilities Alternative No. 5



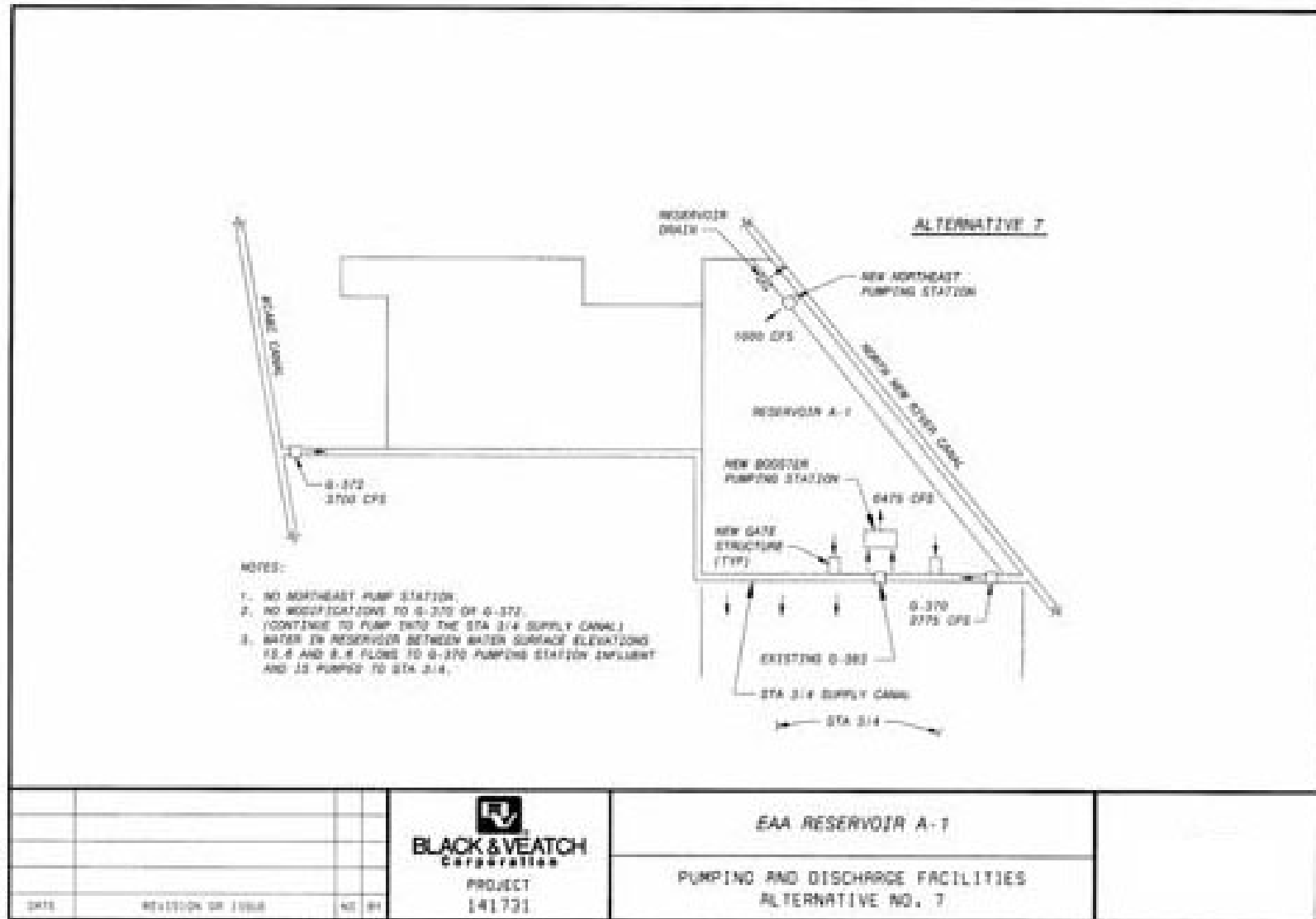
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Figure 13 Pumping and Discharge Facilities Alternative No. 6



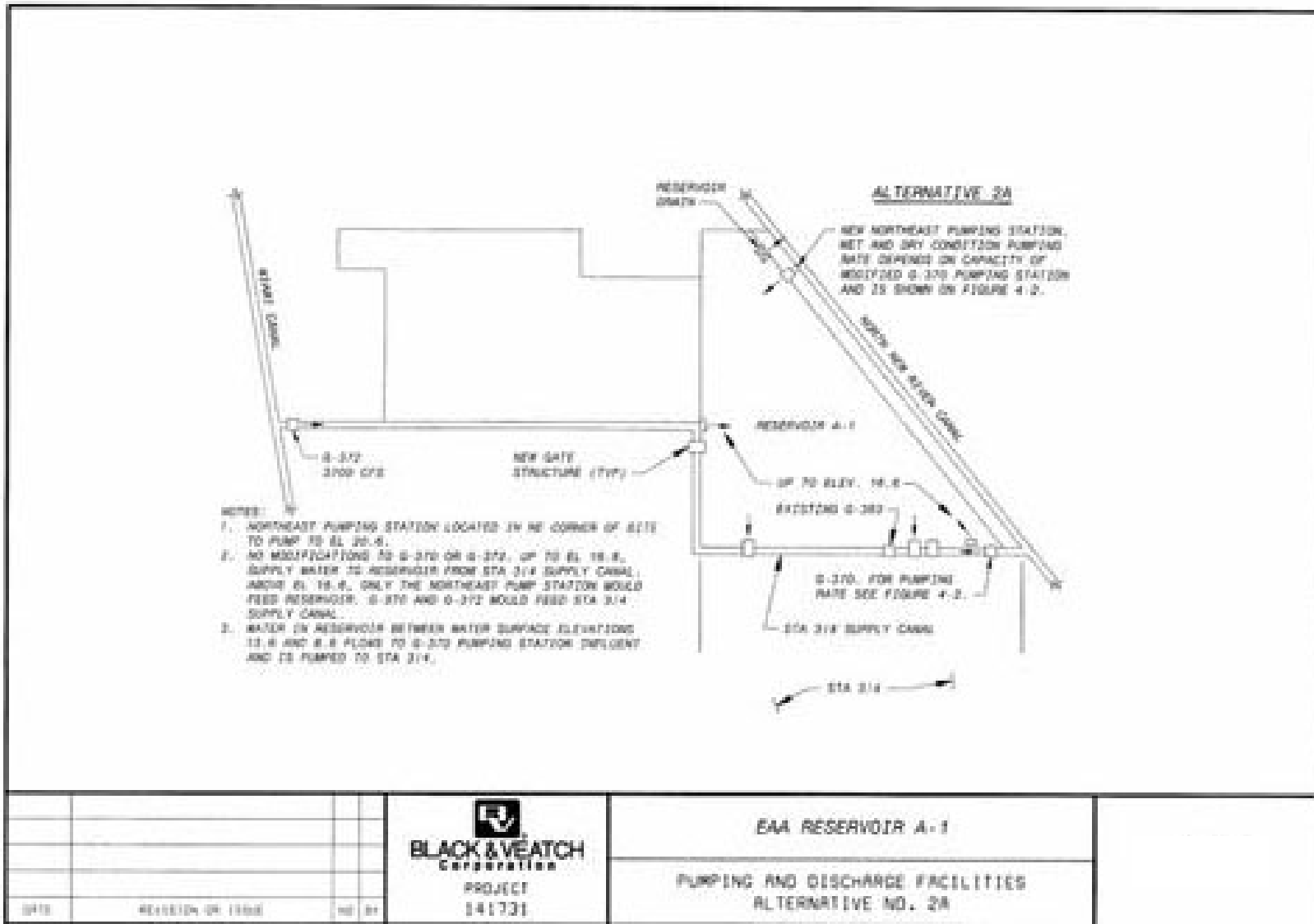
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Figure 14 Pumping and Discharge Facilities Alternative No. 7



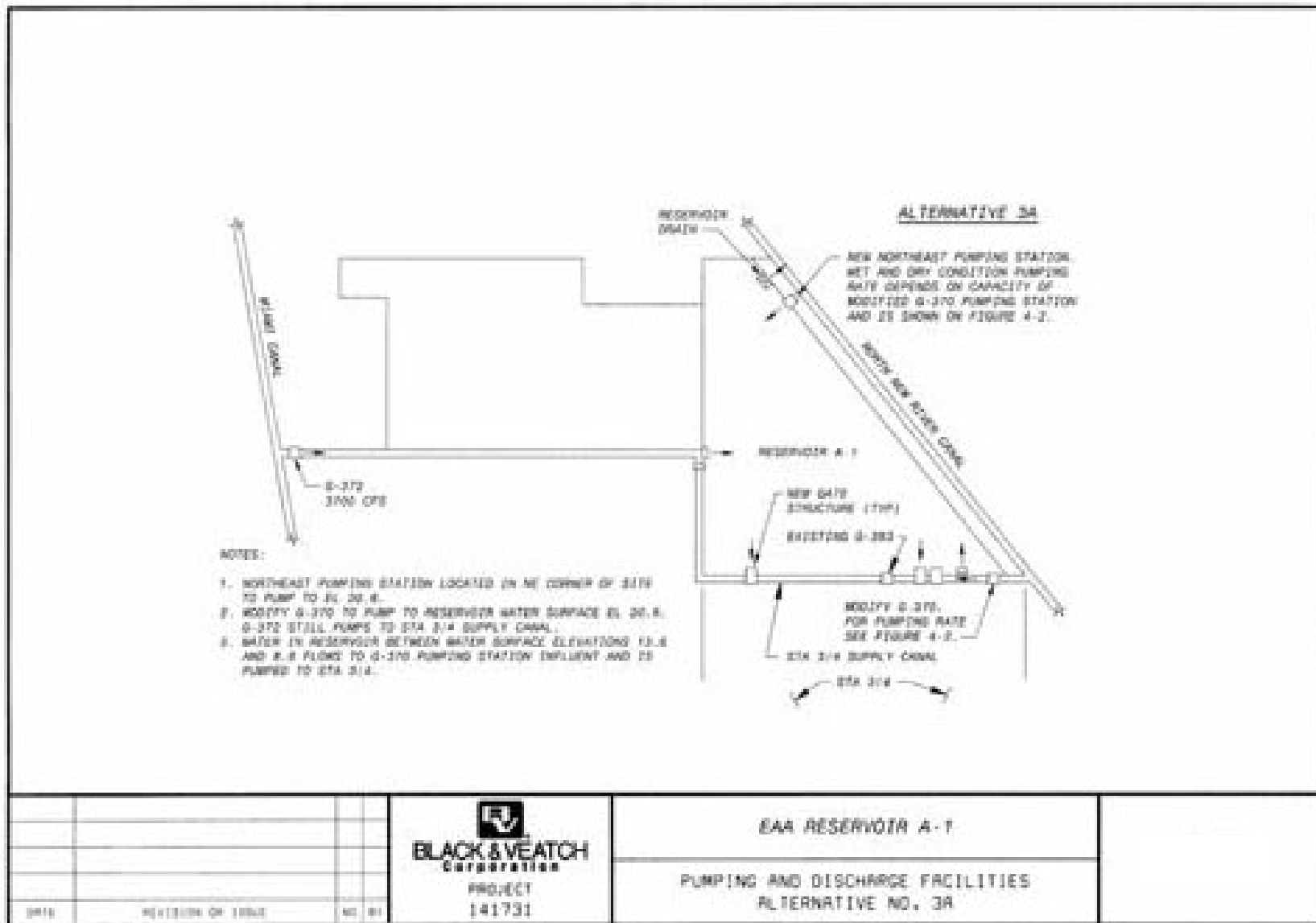
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Figure 15 Pumping and Discharge Facilities Alternative No. 2A



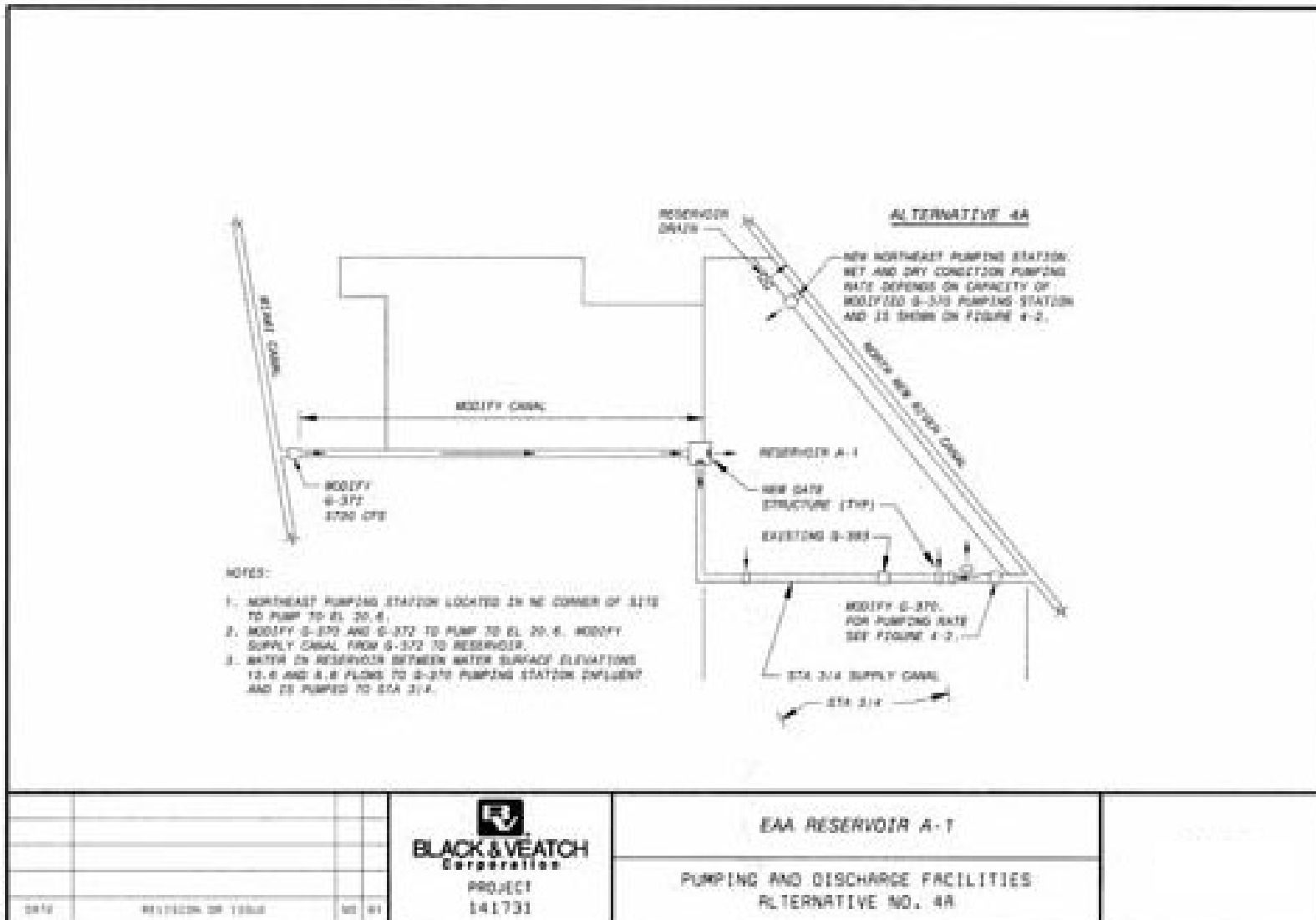
Task 7.1.3.1.2 Pumping and Discharge Facilities Technical Memorandum

Figure 16 Pumping and Discharge Facilities Alternative No. 3A



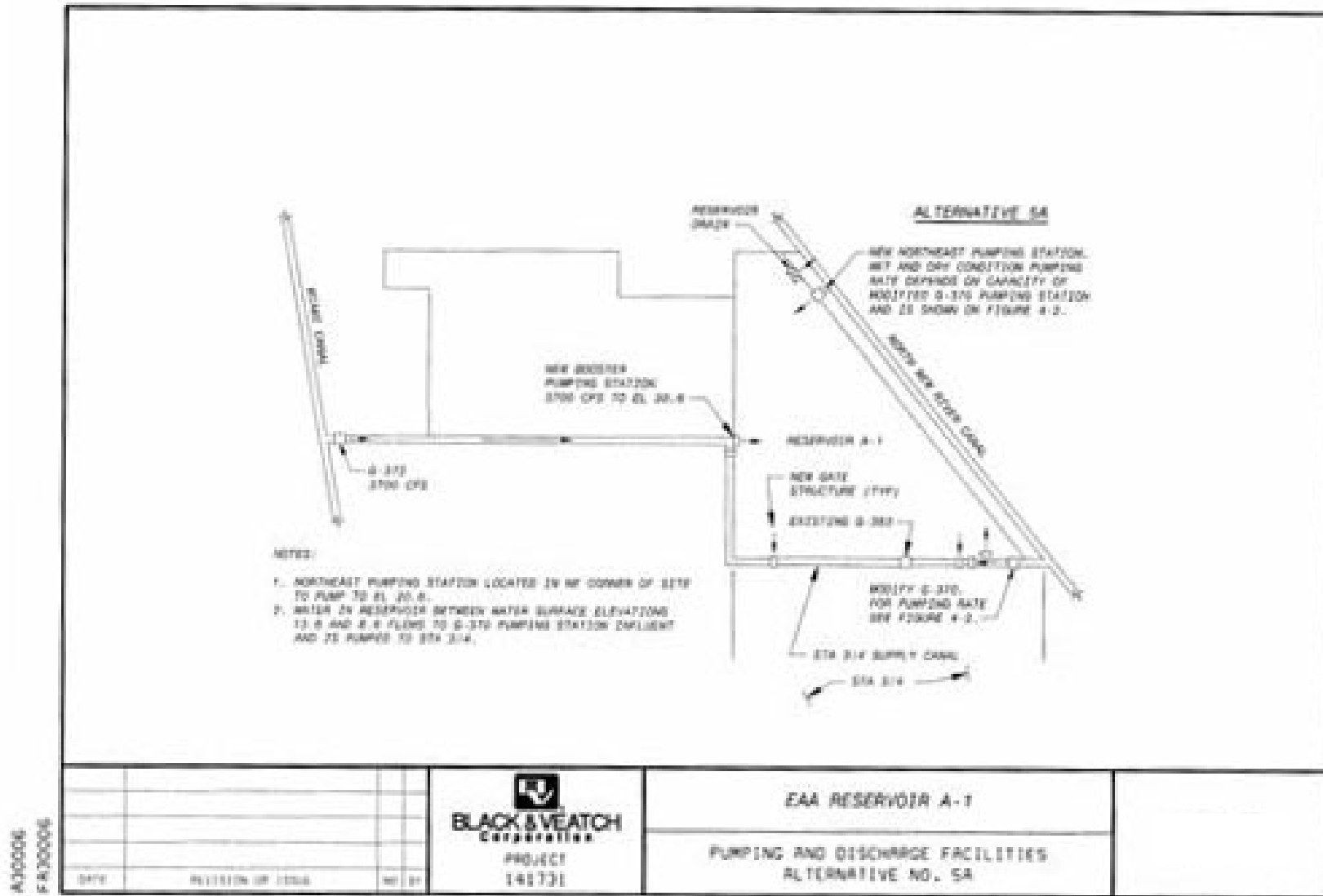
Task 7.1.3.1.2 Pumping and Discharge Facilities Technical Memorandum

Figure 17 Pumping and Discharge Facilities Alternative No. 4A



Task 7.1.3.1.2 Pumping and Discharge Facilities Technical Memorandum

Figure 18 Pumping and Discharge Facilities Alternative No. 5A



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Task 7.1.3.1.2 Pumping and Discharge Facilities Technical Memorandum

ADDENDA

WATER BALANCE MODEL RUNS